Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/bulletincin04univuoft

UNIVERSITY OF CINCINNATI

Bulletin No. 4
October, 1901

Publications of the University of Cincinnati
SERIES II VOL. I

LIBRARY
6 1903
UNIVERSITY OF TORONTO

Observations on the Efferent Neurones in the Electric Lobes of Torpedo Occidentalis —

SHINKISHI HATAI

MDCCCLXX

The University Bulletins are Issued Quarterly

Entered at the Post Office at Cincinnati, Ohio, as second-class matter

UNIVERSITY PRESS
Cincinnati, Ohio

OBSERVATIONS ON THE EFFERENT NEURONES IN THE ELECTRIC LOBES OF TORPEDO OCCIDENTALIS.

By Shinkishi Hatai,

(From the Biological Laboratory of the University of Cincinnati.)

Contents.

I. Materials used and technique employed in the present investigations 1
II. Finer structure of the efferent neurones of the electric lobes in Torpedo occidentalis 2
III. Finer structure of the ground substance of the spinal ganglion cell in the adult white rat 6
IV. Remarks concerning the structure of the ground substance in nerve cells 10
V. Summary 11
VI. Illustrations 12

I. Materials used and technique employed in the present investigation.

For the present investigation, the efferent neurones in the electric lobes of *Torpedo occidentalis*, and the spinal ganglion cells from the mid-cervical ganglia of the adult white rat were used. The body weight of the rat was 141 grams. The torpedo material, which was generously furnished by Dr. Ayers, had been preserved with 10% formaline. To prepare this, a thin piece was cut from the lobe and transferred to distilled water for about six hours in order to remove all the formaline. After thorough washing with water, the material was transferred to 35% alcohol, where it remained about one hour, and then it was carried through graded alcohols and imbedded in paraffine in the usual way. The sections were cut 12 μ in thickness. For staining, a saturated aqueous solution of toluidin blue, and for contrast staining, an alcohol solution of erythrosin, were used.

The spinal ganglion of the white rat was preserved with the author's own mixture (formaline-acetic sublimate mixture) (*), and for staining, the reagents just mentioned were used.

II. FINER STRUCTURE OF THE EFFERENT NEURONES OF THE ELECTRIC LOBES IN TORPEDO OCCIDENTALIS.

The efferent neurones of the electric lobes of *Torpedo occidentalis* are so large, more than 0.1 mm. in diameter, that they can easily be seen with the naked eye. Under moderate magnification, the cell bodies show numerous dendritic processes and the single axone is also visible in most cases.

The general form of the cell body is somewhat similar to that of the motor cells in the ventral horn of the spinal cord in man and the higher mammals. In most cases, the nucleus lies on the side of the cell-body towards the axis-cylinder process. The nucleus is nearly spherical, and very large in size proportionately to the cell-body (40–30 μ). The arrangement of the chromosomes in the nucleus is somewhat peculiar. They do not show minute spherules suspended in the delicate meshwork of the linin substance, but instead of that, irregular large masses which fill up meshes of the linin.

The nucleolus is always visible and lies at one pole of the nucleus. Curiously enough, the nucleolus, as a rule, lies in the same relative position in all the cells of a given section.

Under the higher magnification, the internal structure of the cell-body shows a fibrillar arrangement of the cytoplasm. The nature of this fibrillar structure will be discussed later on. In this chapter, only the general arrangements of these fibrils will be described.

Briefly speaking, the cell-body, except the nucleus presents everywhere a fibrillar arrangement of the cytoplasm. The following descriptions apply to the serial sections of one cell (102 μ in diameter, and 60 μ in thickness), and give a general idea of the structure above mentioned.

(*) Hatai, S.— Finer structure of the spinal ganglion cells in the white rat.—Jour. of Comp. Neurology, Vol. XI, No. 1, 1901.

Fig. 1 is a section passing through the periphery of the cell-body. In this figure, the dendritic processes are shown, but not the neuraxone. The position where the neuraxone will arise in the sections is marked by *A*. The fibrillar bundles which come from all dendritic processes of one side of the cell-body (*a*) take a curving course toward the axone hillock, thus forming an arrangement like an inverted U. Other fibrillar bundles come also from the dendrites on the other side (*b*) and take the same course toward the neuraxone. The dotted areas are interpreted as the cross-sections of the similar fibrillar bundles which, running through the cell-body in different directions, are therefore cut at different angles. In this figure, the fibrillar bundles connecting the dendrites with each other are shown very poorly.

Fig. 2 is the section nearer the center of the cell-body and follows Fig. 1. In this figure, the four dendrites are shown clearly, and the localities of the neuraxone is indicated by "*A*," although it does not appear at this level. The fibrillar bundles which form the neuraxone come from each of the dendrites. The dendrites themselves have close relations with each other by means of the connecting fibrillar bundles passing between them. The nucleus is surrounded by the fibrils coming from one of the dendrites (*c*). The fibrillar bundles which come from the dendrites (*d*) also take a part in investing the nucleus. The cross-sections of the fibrillar bundles show as clearly separated groups.

Fig. 3 is a section passing through the middle of the nucleus and follows Fig. 2. In this figure, the nucleolus is visible. The fibrillar arrangements are slightly different from those in the figures already given. In this section the fibrils do not form large bundles, but are divided into smaller strands and interwoven. The intimate connections between the dendrites are clearly shown. The nucleus is also surrounded by the bundles of the fibrils, which come from some of the dendrites. As a rule, in this level the fibrillar bundles near the nucleus are short, because bundles are, for the most part, cut more or less at right angles to their long axis. This suggests that the fibrillar bundles converge towards the nucleus. The peculiar arrangement of the fibrils near the nucleus has been described as "vortex" or "spiral," or sometimes "Gitterähnliche Anordnung." On the contrary, the fibrillar bundles at the periphery present comparatively long sections. In this section, the neuraxone is not yet shown.

Fig. 4 is a section of the cell-body at another level. In this figure, three dendrites, nucleus, and neuraxone are clearly shown. The neuraxone "*A*" lies at one corner of the base of the rectangular cell-body. An intimate connection of each dendrite with that of the other, and also of all the dendrites with neuraxone is clearly shown in this figure. A curious arrangement of the fibrils is noticeable very near the axone hillock, where the fibrillar bundles have a beautiful spiral arrangement. This spiral arrangement is produced by the fibrils coming from various dendrites as is shown in the illustration. In this figure, connecting fibrils between the dendrites (*a*) and (*c*) are shown very clearly.

Fig. 5 is a section passing through the periphery of the side opposite to that shown in Fig. 1. In this figure, four dendritic processes are plainly shown — one from each corner of a somewhat rectangular-shaped cell-body. The position from where the neuraxone will arise in other section is marked by "*A*." A clear oblong space near the center of the cell-body is the place where the nucleus lies in the other sections. The fibrillar bundles which come from the dendrite (*a*) run towards the dendrites (*c*, *d*) along the one side of the nucleus, and finally enter the dendrites (*c*, *d*). Along the course, a few small fibrillar bundles diverge towards the periphery of the cell-body. The fibrillar bundles which come from the dendrites (*b*) run toward the dendrites (*c*, *d*) in a somewhat similar manner to those from the dendrite (*a*). In this case, the fibrillar bundles divide into two branches at the nucleus and after encircling the nucleus, they enter in the dendrites (*c*, *d*) and become continuous with those from the dendrite (*a*). From the base of the dendrite (*b*), small fibrillar bundles are distributed toward the neuraxone. From the dendrites *c*, *d*, the bundles of fibrils arise, and run toward the neuraxone. Along their course, these bundles are increased by the addition of numerous bundles of fibrils which come from the periphery of the cell-body to form the yet larger bundles found in the axone hillock. The dendrites *a* and *b* are subdivided into two branches. In this case the branches are also connected by a few fibrils. These branches which are divided from the main dendrites (*a*, *b*,) receive fibrils from various regions of the cell-body.

From the above description, two important relations are evident: (1) That each dendrite is connected by the fibrillar bundles with several and possibly all the others, and (2) in each case, the nucleus is partially surrounded or encircled by the fibrillar bundles, on their way from the dendrites to enter into the neuraxone.

As a rule, the fibrils in the dendrites are very conspicuous, presenting long continuous lines, while in the cell-body they take tortuous or irregular courses, so that the cross-section of the cell-body presents minutely dotted areas, representing the cross-section of the bundles. From this, it is inferred that the entire course of some of the bundles must be very complex.

Fig. 6 is a diagram reconstructed from the serial sections of the cell-body in order to depict schematically its structure and to show the fibrillar tracts distributed throughout it. Let us take any one of the dendrites from the Fig. 6, and trace the lines which represent the fibrillar bundles. In the dendrite (*b*), black continuous lines present the out-going fibrillar bundles, while dotted lines in the same dendrite represent the in-coming fibrillar bundles from other dendrites. If we trace one of the black lines (3), it enters into the dendrites which lie in both sides, and other black lines (1) run toward the nucleus and partially encircle it. The fibrils continue from the nucleus toward the axone and finally enter into the axis cylinder. In the remaining dendrites, the fibrillar tracts are just the same in their distribution with those of dendrites (*b*).

In some cases, the fibrillar bundles which run from the dendrite not only enter into the dendrites which lie nearest on both sides, but they also connect with other dendrites further distant (2). In the cross-section of the cell-body, we notice very often the following appearance: The neighborhood of the nucleus is composed of peculiarly arranged fibrils, forming a "spiral" or "swirl." These appearances are caused by the fibrils, which take very irregular courses and partially encircle the nucleus in a tortuous manner.

III. FINER STRUCTURE OF THE GROUND SUBSTANCE OF THE SPINAL GANGLION CELLS IN THE ADULT WHITE RAT.

It remains to discuss the real nature of the fibrillar structures mentioned above, and to this end the structure of the ground substance of the nerve-cells must first be considered.

Concerning the structure of the ground substance in nerve-cells, two main views are held: the "fibrillar" and "non-fibrillar" structure. The former theory may also be subdivided. One view is represented by the theory of Bethe (*) who regards the ground substance as composed of "Peri Fibrillär Substanz" and "Fibrillen." The so-called Fibrillen are independent individuals distributed throughout the cell-body in a certain way, where they neither anastomose nor branch. Another fibrillar theory is that of Apàthy (^{1}). According to this author, the primitive neurofibrils are to be distinguished by means of special technique, in the nerve-cells as Bethe describes. These fibrils however, are not isolated, but are connected with each other by means of delicate branches, thus forming a very complicated anastomosis within the nerve-cells.

The non-fibrillar theories may also be divided into two groups, represented by the theory of Apàthy (^{1}), Nansen (^{2}), Bütschli (^{3}), etc. Nansen holds the view of primitive tubular structure of the formation of the ground substance of the nerve-cells, that is, the ground substance is entirely composed of extremely small tubules which are directly continuous with the neuraxone.

(*) Bethe, A.—Über die Primitiv Fibrillen in den Ganglien-zellen von Menschen und Wirbelthieren.—Arch. für Mikrosk. Anat., Bd. 51.

(1) Apàthy.—Das leitende Element des Nervensystems, u. s. w.—Mitheil. d. Zoolog. Station zu Neapel, B'd XII, '97.

(2) Nansen, F.—The structure and combination of the histological elements of the central nervous system.—Bergen, '87.

(3) Bütschli.—Investigations on microscopic forms and on protoplasm.—'94. Translation to English.

Bütschli, Held (1), Van Gehuchten (2), Von Lenhossek (3), Ramon y Cajal (4), Marinisco (5), Ewing (6), a. o., hold the view of reticular or spongy formation of the ground substance, stating that the fibrillar structure described by others are not true fibrils but rows of fine granules which form the reticular arrangement of the ground substance.

The writer's observations on this subject are as follows: The ground substance of the spinal ganglion cells of the white rat exhibits a reticular structure as shown in Fig. 7. The meshes of the reticulum are very small but conspicuous. The size and form of the meshes vary. Generally, in the clear zone at the periphery of the cell-body, the meshes are always larger and more conspicuous than in the remaining part. In the neighborhood of the axone hillock the meshes are not only much diminished in size, but also they are much elongated along one axis. Around the nucleus, the meshes reach a minimum size. The form of the reticulum at the periphery shows meshes of a somewhat polygonal shape, but in the remaining part of the cell these meshes are elongated, especially around the nucleus and near the neuraxone. Upon examining with a higher magnification, the protoplasmic threads or filaments which forms the reticulum, we see that it is not smooth but has a somewhat varicose appearance, due to the presence of small bead-like arrangements on the course of the filaments. This bead was called by Held (*) a "neurosome," who discovered the occurrence of the neurosome not only at the connecting point of the net but also inside the net. The writer noticed the occurrence of these structures not only at the connecting points of the net but also in the course of the filament, but could not find them inside the reticulum.

---

(1) Held.—Beiträge zur Strukturen der Nerven-zellen und ihren Fortsätze.—Erste Abhandlung. Arch. für Anat. und Entwickelungs. Anat. Abth., '95.

(2) Van Gehuchten.—Anatomie du systèm nerveux de l'homme.—Lauvain, 1894.

(3) Von Lenhossek.—Feinere Bau des Nervensystems.—'95. P. 147.

(4) Cajal.—Estructura del protoplasma nerviso.—Revista trimestral micrografica, Vol. I, fasc. 1, '96.

(5) Marinisco.—Pathologie gènèrale de la cellule nerveuse.—La Presse Médicale, '97.

(6) Ewing.—Studies on ganglion cells.—Arch. of Neurol. and Psychopathol., Vol. I, No. 3. '98.

(*) Held.—Loc. cit.

This bead or neurosome has peculiar chemical affinities for the staining fluids. Eosin or erythrosin stain this element very deeply, so that it can easily be distinguished from the rest of structures. The fine filament joining these beads seems to be slightly different from the neurosome itself, as is shown by a slightly different staining reaction. It seems, indeed, that these neurosomes are a highly differentiated portion of the protoplasm which forms the reticulum.

The form and size of the neurosomes are different in different localities, as has been already described by Held. These structures are especially numerous within the axone hillock and intracellular extension of the axone. At the periphery of the spinal ganglion cells, the individual meshes of the reticulum are so large that the neurosomes are less crowded, hence, in this region, they are scattered very irregularly. But on the contrary, in the remaining parts of the cell, the meshes of the reticulum are elongated in shape and the rows of neurosomes become more crowded together, thus giving the fibrillar appearence. At first glance, this arrangement of neurosomes looks very much like the fibrils which have been described by many authors. Careful observations, however, show that these lines appearing like fibrils are composed of a row of minute beads arranged serially. Moreover, these pseudo-fibrils are connected by protoplasmic threads, thus forming the reticulum. This structure is shown in Fig. 7. Around the nucleus these neurosomes form somewhat concentric lines in a very beautiful manner. But gradually the figure becomes irregular as the reticulum approaches the periphery. This is the appearance generally found in the spinal ganglion cells. Sometimes the cell shows different arrangement of neurosomes, namely, concentric lines at the periphery but not in the neighborhood of nucleus. Still other variations in arrangement are found.

Graf (*) noticed the fibrils which are composed of a row of minute beads, in the Purkinji cells of human cerebellar cortex. He said: "The cytoplasma show the most beautiful fibrillar structure that I have ever seen. The fibrillæ are exceedingly fine and are very regularly arranged in the cell-processes and on the surface of the cell, whereas they form a more intricate network in the center of the cell, especially around the nucleus. By closer observation of a favorable spot (the best places are where the stain is not very intensive) we notice that the finest cytoplasmic fibrillæ are not smooth, like smooth muscle fibrils, for instance, but are composed of a row of minute beads closely arranged in single file."

---

*) Graf, A.—On the use and properties of a new fixing fluid (chrom-oxalic.)—Bull. of Pathol. Institute of the New York Hospitals, '97. Vol. II, p. 386.

Held believes that the fibrils, according to some investigators, are in reality identical with rows of neurosomes. He hints that some of the fibrils represent bands of neurosomes; other fibrils described by Flemming are bundles of cytospongium.

My own observations support Held's suggestion. My preparations show sometimes exactly the fibrillar structure described by Graf, and I find this condition in the efferent neurones of the Torpedo, as well as in the spinal ganglion cells in the white rat. These fibrils can always be resolved into rows of neurosomes.

Another important point is, that the meshes of the reticulum in the cell-body become more and more elongated toward the axis cylinder. Thus it looks as if the fibrils are radiating from the axone around the nucleus.

The peculiar character of the region from where the axis cylinder originates was first described by Schäffer (1).

This region of the cell-body he called the "axone hillock." It is admitted by most investigators that the axone hillock, as well as the axis cylinder, show a parallel arrangement of cytoplasm. The writer notices also these arrangements of fine cytoplasmic threads, which carry the neurosomes, showing a convergent arrangement toward the axis cylinder. In this region the meshes of the reticulum are very small, but careful examination shows that the axone hillock, as well as axis cylinder, are composed of an altered reticulum.

The arrangement of neurosomes, except in the axone hillock, is not the same in all nerve-cells, but differs according to the type of the cells.

---

(1) Schäffer, K.—Kurze Anmerkung über die Morphologische Differenz des Axen Cylinders in Verhältnisse zu dem Protoplasmatischen Fortsätze bei Nissl's Färbung.—Neurol. Centralbl., Leipzig, Bd. XII, '93, S. 849-851.

In the motor ganglion cells in the anterior horn of the spinal cord, the neurosome presents quite a different arrangement from that of spinal ganglion cells. In the former group the meshes of the reticulum do not show the honey-comb form, but an elongated shape. The cytoplasmic thread carries a great number of neurosomes, which form straight chains. These chains run parallel to the periphery toward the dendrites, as well as toward the axis cylinder. Around the nucleus, however, these chains have the arrangement found in the spinal ganglion cells.

The Purkinjii cells in cerebellar cortex in the white rat show still a different arrangement of neurosomes. In these cells the neurosomes accumulate at the base of the main dendrites, showing very intricate arrangement. But near the entrance of the dendrites the irregular chains rearrange themselves, forming a regular line of neurosomic fibrils. The remaining part of the cell-body show nearly the same arrangement as that of the spinal ganglion cells.

IV.—REMARKS CONCERNING THE STRUCTURE OF THE GROUND SUBSTANCE IN NERVE CELLS.

As has been mentioned already, the ground substance of the spinal ganglion cells of the white rat presents very clearly the reticular structure. This structure, however, is altered by the growth of cell-body; for example, the prolongation of the axis cylinder from the cell-body is accompanied by an elongation of the primitively polygonal meshes of the reticulum, thus giving a fibrillar appearance to the ground substance.

The same holds true in the case of the Torpedo. The apparent fibrils result from alterations in the reticulum, and, therefore, should not be compared to those of Bethe's. Although, in the case of the Torpedo, the reticulum is hard to see, yet it is sometimes clearly demonstrable in thin sections properly stained.

In the spinal ganglion cells of the higher mammalia, except in Dogiel's second type of cells, the cell-body sends off only one prolongation, while in the case of Torpedo, the efferent neurones of the electric organ give numerous processes from the cell-body. In the former case, the meshes of the reticulum are changed gradually from a regular polygonal form to those much drawn-out in the axone hillock. In the case of the Torpedo, however, the arrangement of the reticulum is modified not only toward the axis cylinder, but in every part of the cell-body from which dendritic processes arise. The appearances in Torpedo can be explained as a result of the growth changes of the cell-body. Judging from what we find in the rat, we assume in the first place the spinal ganglion cell to be a spherical mass filled by the wide meshed reticulum. For the same reason we assume that this spherical mass is pulled out at each point where there is a dendrite, and thus modified as it is where the neuraxone is formed from the axone hillock. As a result, the primitive polygonal meshes are transformed mechanically by the growth changes and thus give rise to the fibrillar appearance. If numerous processes are formed by the cell, as in the case of Torpedo, then the resulting appearance is quite complex. But the principle of its formation is the same as in the more simple spinal ganglion cell. The so-called fibrillar arrangement in the writer's preparation is thus explained:

V.—SUMMARY.

1. The efferent neurones of the electric lobes of *Torpedo occidentalis* present a fibrillar appearance of the ground substance.

2. This appearance, however, is due to an alteration in the shape of the meshes of the reticulum, and, therefore, it cannot be compared with the fibrils described by Bethe, Apàthy, and others.

3. The meshes of the reticulum, which are regarded as the primitive by the present writer, are altered by the growth of the cell-body where the processes, both axone and dendrite, arise and become extremely elongated in these branches.

4. Gradations from the primitive shape of the meshes to the altered form which appears fibrillar, are clearly visible in the spinal ganglion cells of the white rat.

VI.—ILLUSTRATIONS. (Plate I.)

FIG. 1–5—Five serial sections from a single efferent neurone in electric lobe of *Torpedo occidentalis.* Mean diameter of the cell-body (120 μ x 83 μ); of the nuclei (37 μ x 34 μ).

FIG. 6—Diagram showing the fibrillar arrangement of the efferent neurone in an electric lobe of *Torpedo occidentalis.*

FIG. 7—Spinal ganglion cell from the mid-cervical ganglia of the adult white rat. Cell-body (41 μ x 30 μ); nucleus (15 μ x 15 μ).

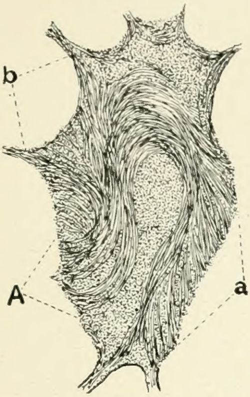

Fig. 1.

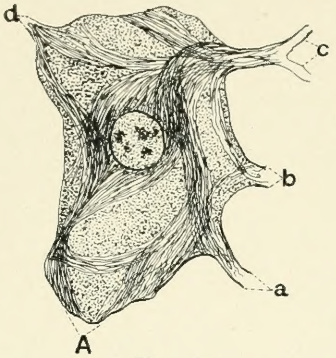

Fig. 2.

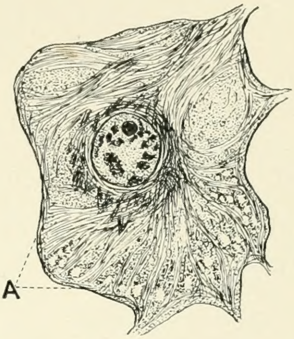

Fig. 3.

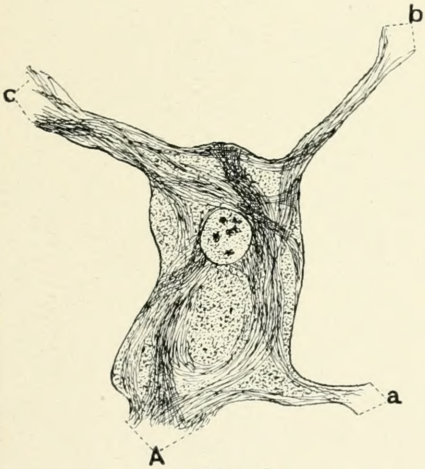

Fig. 4.

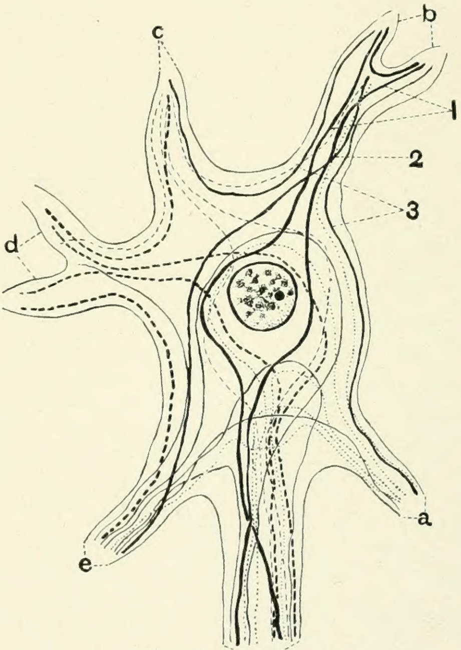

Fig. 6.

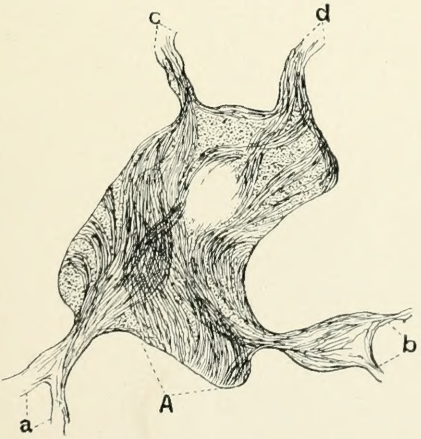

Fig. 5.

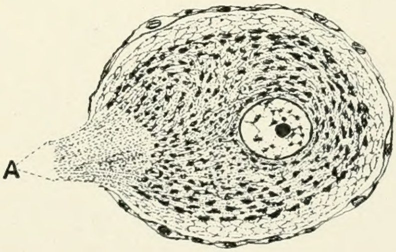

Fig. 7.